depleted in incompatible elements may still be valid for inferring the global K/Th ratio. The difference between the behavior of the K/Th ratio for lunar and Martian samples with Th abundances of $\sim$0.2 ppm likely result from the different origins of these materials, as the lunar samples represent material formed during magma ocean crystallization whereas the Martian samples represent products of partial melting of depleted mantle. The evidence for extensive volcanic material on the surface of Mercury suggests that the Martian meteorites may be better analogues for understanding the K/Th ratio in the limit of low Th.

5.4. Relation to Surface Temperature

[40] The comparatively volatile nature of K, along with the possibility that a secondary process may be modifying the K/Th ratio on the surface (section 5.2), raises the question of whether surface temperature may play a role in modifying the near-surface abundances of K. To test this hypothesis, the distribution of measured K abundances was compared with models of the maximum temperature [*Vasavada et al.*, 1999] reached at depths comparable to the sensitivity of gamma-ray spectroscopy ($\leq$ tens of centimeters). The profile of surface temperature on Mercury results in a bimodal distribution of maximum values centered at the equator and at 0° and 180° longitudes, collectively termed Mercury's hot poles [*Soter and Ulrichs*, 1967]. These hot poles are the result of the relatively large eccentricity of Mercury's orbit around the Sun coupled with its 3:2 spin-orbit resonance, which places these longitudes at local noon during alternating perihelia. The maximum surface temperature at a depth of 7 cm (Figure 11) was compared with the GRS-derived K abundance map (Figure 8) by measuring the correlation coefficient R between the two parameters (Figure 12) both for all temperatures as well as just those above 350 Kelvin (see section 6). The R values (-0.82 and -0.84, respectively) suggests a high probability that the K abundance is anti-correlated with the maximum surface temperature. This anti-correlation is also observed for the temperature at depths of 0 and 15 cm.

[41] If temperature-driven processes are modifying the surface K abundances, then two possibilities present themselves. K may be preferentially lost to the exosphere, which is known to have a measurable K component (section 6), resulting in a permanent loss of K from the surface. Alternatively, the dominant effect may be that K is redistributed to the surface in cooler polar regions. In the first case, the present K abundances provide an underestimate of the planetary K/Th ratio. In the second case, the northern-hemisphere average values presented here and by *Peplowski et al.* [2011b] may be a valid representation of the global value since this scenario does not result in a net loss of K from the planet, although the GRS-derived elemental abundances are determined under the assumption of a uniform composition within the depth sensitivity of gamma-ray spectroscopy (upper tens of centimeters). If near-equatorial K is being redeposited in the polar regions only within a thin veneer, then the K abundances presented here may overestimate the actual values.

[42] The existence of a veneer of K that is biasing the GRS-measured K abundances is considered unlikely, however, in the presence of regolith gardening, a process that continually overturns near-surface material through repetitive small impacts. For the 1461-keV K gamma ray in regolith with a Mercury-like composition [*Nittler et al.*, 2011; *Peplowski et al.*, 2011b; Evans et al., submitted, 2012], 90% of the surface gamma-ray flux originates from the top 20 cm of the regolith, and 50% originates from the top 6 cm. Lunar regolith overturn timescales for the top 6 cm are 10^7–10^8 y per complete overturn with a probability of 50–99% [*Hörz et al.*, 1991]. On the basis of scaled meteoroid influxes, *Killen et al.* [2007] estimated that the timescale for regolith overturn on Mercury is 0.15 times the lunar value, which leads to an estimate of 10^6-10^7 y per overturn and a total of 10–100 overturns over the age of Mercury. As Mercury's 3:2 spin-orbit resonance is stable [*Colombo and Shapiro*, 1966; *Goldreich and Peale*, 1966], it is unlikely that the thermal conditions at the hot poles have appreciably changed on a timescale that is shorter than that for regolith overturn. As a result, if near-equatorial K is being redeposited in the polar regions, the resulting veneer has been well mixed within the top tens of centimeters of the regolith and is therefore not biasing GRS measurements of the K abundance.

[43] The observed correlation between the K abundance and the maximum surface temperature offers a possible explanation for observation that the XRS-measured composition of the Caloris basin and the northern volcanic plains are similar [*Weider et al.*, 2012], whereas they differ significantly in their K abundances. Given that the Caloris basin interior plains are volcanic in origin [*Watters et al.*, 2009], the material may have originally been enriched in incompatible elements such as K and Th. The position of Caloris basin near one of Mercury's hot poles, however, may have depleted the near-surface K but would have left the Th abundance comparatively unaltered. This explanation also accounts for the unusually low K/Th abundance ratio for this region (Figure 9 and Table 4), which is found to be considerably lower than the other regions examined here.

6. Implications for the Exosphere

[44] The results of section 5.3 suggest that the relatively low K concentrations measured by the GRS near Mercury's hot poles might be the result of thermally driven diffusion of K out of near-surface regolith to the gas–surface interface, where it is then lost to the exosphere or transported to polar regions. One likely host mineral for K (and the volatile Na also observed in the exosphere) is alkali-bearing feldspars. Diffusion rates in feldspars have been measured at temperatures of 600–1000 Kelvin [*Giletti and Shanahan*, 1997]. A linear extrapolation of these diffusion rates to 300–500 Kelvin suggests that 10 μm grains would lose K on timescales of about 500,000 yr at 500 Kelvin. Even grains approaching 1 mm in size would lose K in several billion years. However, 10 μm grains would require timescales greatly exceeding the age of the Solar System to lose K at 300 Kelvin. These differences in the diffusion rate are fully consistent with the observed relationship between the measured K abundances and maximum surface temperatures (Figure 12) could therefore account for the loss of K from equatorial regions and its retention in cooler polar regions.

[45] Any ejection mechanism, such as thermal desorption [*Sprague*, 1990, 1992] or diffusion-limited photodesorption [*Killen et al.*, 2004], can populate the exosphere. *Domingue et al.* [2007] provided a thorough discussion of release